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Observations on regeneration after fire in the Yule Brook Reserve near Perth, Western Australia

by A. M. Baird

Botany Department, University of Western Australia, Nedlands, W.A. 6009.

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Abstract

Yule Brook Reserve, a swampy flat, dry in summer and crossed by two sand ridges, has been burnt several times in the past 25 years. This paper is based on notes and photographs taken over this period to record the regeneration after each fire.

On the sandy ridges recovery of the banksia woodland and shrub cover of the almost treeless slopes is rapid as the trees are not seriously damaged and almost all shrub and monocotyledon species sprout from underground parts.

On the wetlands, i.e. *Leptocarpus* sward of the main level of the flats, the *Actinostrobus* mixed scrub and the *Leptospermum-Restio* low scrub, the dominant species of each of the communities are killed by fire and regeneration by seedlings is slow in the difficult habitat, waterlogged through winter and very dry in summer. However, subordinate species, i.e. small perennials and the many geophytes and annuals, with the competition of the dominants reduced, flourish in the first few years of the succession.

In parts frequently burnt there seems to be some reduction in fire sensitive species particularly *Leptospermum ellipticum, Actinostrobus pyramidalis* and *Banksia telmatiaea.* A general deterioration of vegetation over the flats has been observed but to what extent this is due to frequent fires, drought, or increased salinity is as yet uncertain.

Introduction

Yule Brook Reserve of 35 hectares is located 20 km south east of Perth (32° S 115° W) on a section of flats on the coastal plain at the foot of the Darling Scarp.

The site is a swampy flat (Fig. 1) crossed by two parallel sand ridges running north and south, the main eastern ridge (Fig. 3) being higher and more extensive than the low ridge (Fig. 2). The soil of the flats is shallow white sand over clay which extends under the deep sand of the ridges. The flats are waterlogged through winter and dry and hot in summer.

A general account of the vegetation was given in the first paper of this series (Speck and Baird 1984) but may be briefly summarised here. Banksia woodland occurs on the crest of the main ridge (Fig. 3) with low shrub undergrowth continuous with the dense low shrub community of the almost treeless slopes (Fig. 3H). The low ridge has similar low shrub cover but no banksia trees. The flats are covered by a sward of the twine rush *Leptocarpus aristatus* (Fig. 4C). Scattered unevenly through the flats are saline depressions and low shrub covered mounds (Figs. 1, 5H). Intermediate levels at the foot of the ridges have shrub communities dominated by *Leptospermum ellipticum* (Fig. 7E) or *Actinostrobus pyramidalis* (Fig. 7F).

Fires have been frequent on the reserve. In 1958, 1964, 1967 and 1972 (Fig. 1) summer fires burnt big sections of ridges and flats. The southern end of the main ridge has escaped all these fires but most parts have been burnt twice and other parts three or four times in 25 years. Appendix 1 shows the approximate position and extent of these fires.

This paper results from observations and photographs of the regeneration following each of these fires. Later fires are being monitored by present members of the University of Western Australia Botany Department. It is hoped that these notes and photographs may be useful in assessing changes in the area and providing a background for future detailed work.

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Regeneration of vegetation

The ridges—woodland and shrub communities.

On the ridges where almost all the undergrowth plants regenerate by sprouting from underground parts, the vegetation rapidly recovers its prefire appearance. As there is no dominance by any one species in the unburnt bush, so there is none in regeneration, although in the first year the more rapid recovery and flowering of some species makes them more conspicuous than those growing more slowly and not flowering until the second year. In general the minor changes in relative proportions of different species of similar life forms alters the overall character of the undergrowth very little. There is a steady build-up of the shrub cover over the years following fires, with some taller species gradually projecting above the general low level of the undergrowth.

Some details of the regeneration on each of the sand ridges is given below and some photographs in Figures 2 and 3.

On the low western ridge (Fig. 2) after the March 1958 fire by May shoots were just visible on most of the burnt off shrubs but the perennial monocotyledons had made far more growth. By August-September *Anigozanthos humilis* in full bloom gave a spectacular display. Also flowering were *Conostylis juncea*, the orchid *Caladenia flava* and the sedge *Schoenus curvifolius*. Through October-November the more massive monocotyledons, *Dasypogon bromeliifolius* (Fig. 2B) and the purple iris *Patersonia occidentalis* were in full bloom with the less conspicuous tall dark flowering stems of *Haemdorum spicatum* and the twisted stems of *Lyginia barbata*. The annual grass *Stipa compressa*, seen only after fires, formed a sparse cover over the ridge (Figs. 2A, B) and the annual composite *Podotheca chrysantha* was abundant. By this time there had been considerable regrowth on the dicotyledon shrubs (Fig. 2C) although few flowered in the first year. Common species included *Eremaea pauciflora, Hibbertia hypericoides, H. racemosa, Bossiaea eriocarpa,* and *Hovea trisperma.*

Certain species flower only (or almost only) after fire e.g. *Stirlingia latifolia, Xanthorrhoea preissii, Stipa compressa, Lyperanthus nigricans, Stylidium carnosum.* Other species flower more profusely although not exclusively.

Figure 1.—General view looking east across the flat to the banksia ridge May 1972. The ridge and a strip of the flat was burnt February 1972, the adjacent section of *Leptocarpus* sward and low mound was burnt January 1967; the foreground, a saline patch too bare to carry fire and the zone behind it with shrubs, escaped the 1967 fire. The small dark shrubs on the saline patch are the succulent *Halosarcia.*

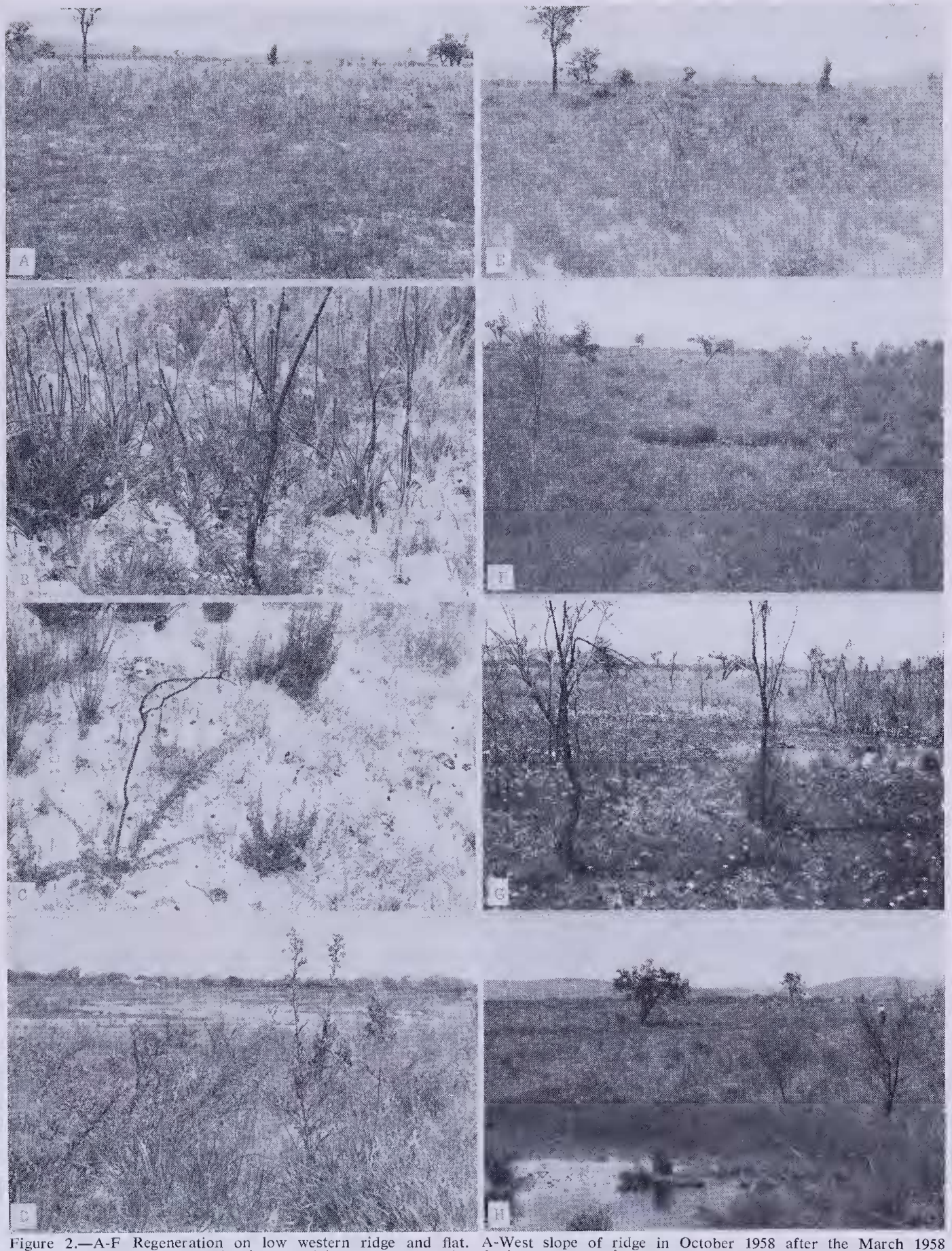

Figure 2.—A-F Regeneration on low western ridge and flat. A-West slope of ridge in October 1958 after the March 1958 fire. *Stipa compressa* showing as light colour on ridge; herbs on flat in foreground; *Nuytsia* trees left, Darling Scarp in distance. B.-Detail of regrowth on ridge. *Dasypogon bromeliifolius* in bud, wispy *Stipa compressa*, dark flower stems of *Haemodorum* right. October 1958. C.-*Acacia pulchella* with shoots from base of blackened stem, *Hibbertia hypericoides* regrowth right, *Amphipogon* left. October 1958. D.-Second year regrowth on edge of main ridge. *Jacksonia floribunda* projecting. October 1959. E.-Same site as A one year later, low shrub regrowth on ridge. October 1959. F.-Same flat and ridge slightly to right of A. *Viminaria* to right and single plant left. Regeneration in 6th year after another fire in January 1967. *Leptocarpus* restored to flowering stage in foreground. August 1972. G.-Same site as F (cf. forked *Nuytsia* on ridge) in the first spring after another fire in January 1976. *Stipa compressa* covering the ridge, *Tribonanthes variabilis and Drosera gigantea* in flower on the flat. September 1976. H.-Same site photographed in 1955, probably burnt in 1949. Photographs looking E to Darling Range on skyline.

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Figure 3.—Regeneration on main ridge. A-E Western side, F-H eastern slope. A.-Slope from flat up to the banksia woodland burnt February 1972. May 1972. B.-Recovery in first year after fire in January 1964 epicormic shoots along branches of trees, new foliage on *Xanthorrhoea*, undergrowth with *Stipa compressa* showing pale; dead *Leptospermum* stems in foreground. December 1st 1964. C.-Detail of regenerating undergrowth, *Jacksonia floribunda* left of centre *Haemodorum* and *Patersonia* right of trowel, *Amphipogon* behind. December 1st 1964. D.-Second year regeneration. Tree canopy recovering, shrub regrowth established, *Patersonia* in flower, old spikes of *Xanthorrhoea* which flowered in 1964. October 26th 1965. E.-Regeneration in the sixth year on upper slope, *Eremaea* L.H. corner, dense cover comprising many shrub species, young *Banksia* trees left and right with pale new shoots. December 9th 1969. F.-*Adenanthos* from a 1964 seedling, centre, *Jacksonia, Eremaea* and other shruhs behind, *Patersonia* on front margin. December 9th 1969. G.-Part of the shrub cover, *Calytrix aurea* in flower *Conospermum* centre back, *Stirlingia* lower right corner. December 1969. H.-General view looking down eastern slope to *Nuytsia* trees and a group of coppice *Eucalyptus calophylla*. The dense shrub cover restored. December 1969.

By the spring of the second year the low shrub cover was re-established and the plants blooming well. Bare sand still remained to be gradually covered in succeeding years. Some of the bare areas on this ridge were due to remains of old rabbit burrows. Another fire over the same ridge in January 1967 was followed by similar recovery with monocotyledons flowering in the first spring and summer and *Stipa compressa*, not seen in the intervening years, again conspicuous. Figure 2F shows regrowth in the sixth year after the 1967 fire and 2G the same site in the first year after another fire in 1976 with *Stipa compressa* covering the ridge and *Tribonanthes variabilis* and *Drosera gigantea* in flower on the blackened flat.

On the tree crested eastern ridge (Fig. 3) most of the Banksias were defoliated in each of the 1958, 1964 and 1972 fires, the leaves being scorched in the fire and falling subsequently. The extent of crown damage varied along the ridge. Recovery was by growth of epicormic shoots along the upper branches (Fig. 3B). A few seedlings of *Banksia menziesii* and *Banksia attenuata* were found. In 1964 the *Nuytsia* trees on the lower slopes (Fig. 3H) produced a spectacular display of flowers on almost leafless blackened stems. In the following year the foliage had made good recovery but there were few flowers. Similar prolific flowering occurred on trees on the western ridge in the first year after a fire in 1967.

Regeneration of the undergrowth of the woodland and of the almost treeless slopes was similar for that described for the low ridge, with early growth and flowering of monocotyledons and sprouting of almost all shrubs. Figure 3 shows a few stages in the recovery, Figure 3C in December of the first year, 3D in the second and Figures 3E, F, G, H in the sixth year when the dense shrub cover was fully re-established.

Seedlings were few for most of the sprouting shrubs. However, the sprouting *Jacksonia floribunda* (Fig. 2D) produced numerous seedlings. These started with juvenile foliage of true leaves before the adult foliage of leaf like phylloclades. The combination of sprouting from a probably long lived lignotuber and post fire seedling regeneration makes this one of the most fire tolerant shrubs. *Acacia pulchella*, which in the woodland in Kings Park (Baird 1977) is invariably klled by fire, survived and produced shoots from the base of the stem (Fig. 2C) in at least 50% of the plants although there is no lignotuber or thickened tap root which are usual for sprouting species. As in sites where the plants are killed seedlings were numerous.

Few species on the ridge were killed by fire, *Adenanthos cygnorum* a tall grey foliaged shrub was the one species noticeably lacking in the newly burnt areas. However seedlings were numerous and although only 1-4 cm tall after one year grew more rapidly subsequently. Figure 3F shows a 5.5 year old plant. Smaller shrub species killed but regenerating from seed were *Leucopogon conostephioides*, abundant on the wooded eastern ridge, several other epacrids and the legume *Gompholobium tomentosum*.

In 1970 there was on the main ridge a small section long-unburnt at the southern end, a section burnt in 1958 and not since, a big area burnt in 1964 with small incomplete 1967 burns over part of it (Appendix 1). In the unburnt part there was a dense tree canopy including some almost tree size *Adenanthos*, and rather straggly undergrowth with much dead wood. In the 13 year old regeneration the shrub cover was dense with *Leucopogon conostephioides* (ca. 1m) abundant across the ridge, and a lower story including *Hibbertia* (2 spp), *Hovea*, *Bossiaea*, and *Eremaea*. The taller *Acacia pulchella* was mostly dead or dying. The fringe of *Adenanthos* which had been conspicuous outside the banksia before the 1958 fire was in evidence again. In the 1964 extensively burnt area the tree canopy was only partially recovered but the undergrowth was in good condition with the fire sensitive *Leucopogon consostephioides* present again and flowering although the plants were still small (15-20 cm). The shrub cover on the eastern treeless slope (Fig. 3G, H) was almost fully recovered with healthy compact flowering bushes of the sprouting shrubs and persistent monocots. *Adenanthos* plants grown from seed were now sturdy bushes (Fig. 3F). Colonies of *Conospermum* on the upper slopes had regenerated early by many and vigorous long leafy sprouts in the first year and had flowered in the second but had grown progressly more slowly since.

As easily recognisable projection into the flat at the western foot of the main ridge has been photographed since 1958 to show regeneration from a March fire of that year and another in 1972. Figure 6 shows a few stages in the recovery on the flat and slopes.

A tall old paperbark (*Melaleuca preissiana*) was burnt through near its base and the fallen trunk can be seen in the photographs. By November 1958 (Fig. 6A) there had been little growth on the trees and the annual grass *Stipa compressa* was obscuring the early shrub regrowth. On the flat the ground was bare except for the burnt bases of the non regenerating *Leptocarpus* and a few herbs. A year later (Fig. 6B) epicormic shoots on the trees were well developed and there was a dense regrowth of *Acacia saligna*. On the flat seedlings of *Leptocarpus* formed a faint grey film.

Figure 6C in October 1965 gives a more distant view to show the site in relation to the edge of the ridge and part of the flat with the 1964 firebreak. The sward of *Leptocarpus* was restored and there had been massive regrowth from the base of the burnt *Melaleuca*. This is shown more clearly in Figure 6D, November 1970. *Actinostrobus* regenerated from seed formed a group of slender plants projecting above the Acacia scrub.

In 1972 another fire engulfed this site and left it as in Fig. 6E. In the fourth year of recovery from this (Fig. 6F) again there had been a dense regrowth of *Acacia saligna*. The *Leptocarpus* on the flat had regenerated well, much better than on the open flat no doubt because seepage of fresh water from the ridge and drainage along the firebreak checked the development of salinity present on the central part of the flat.

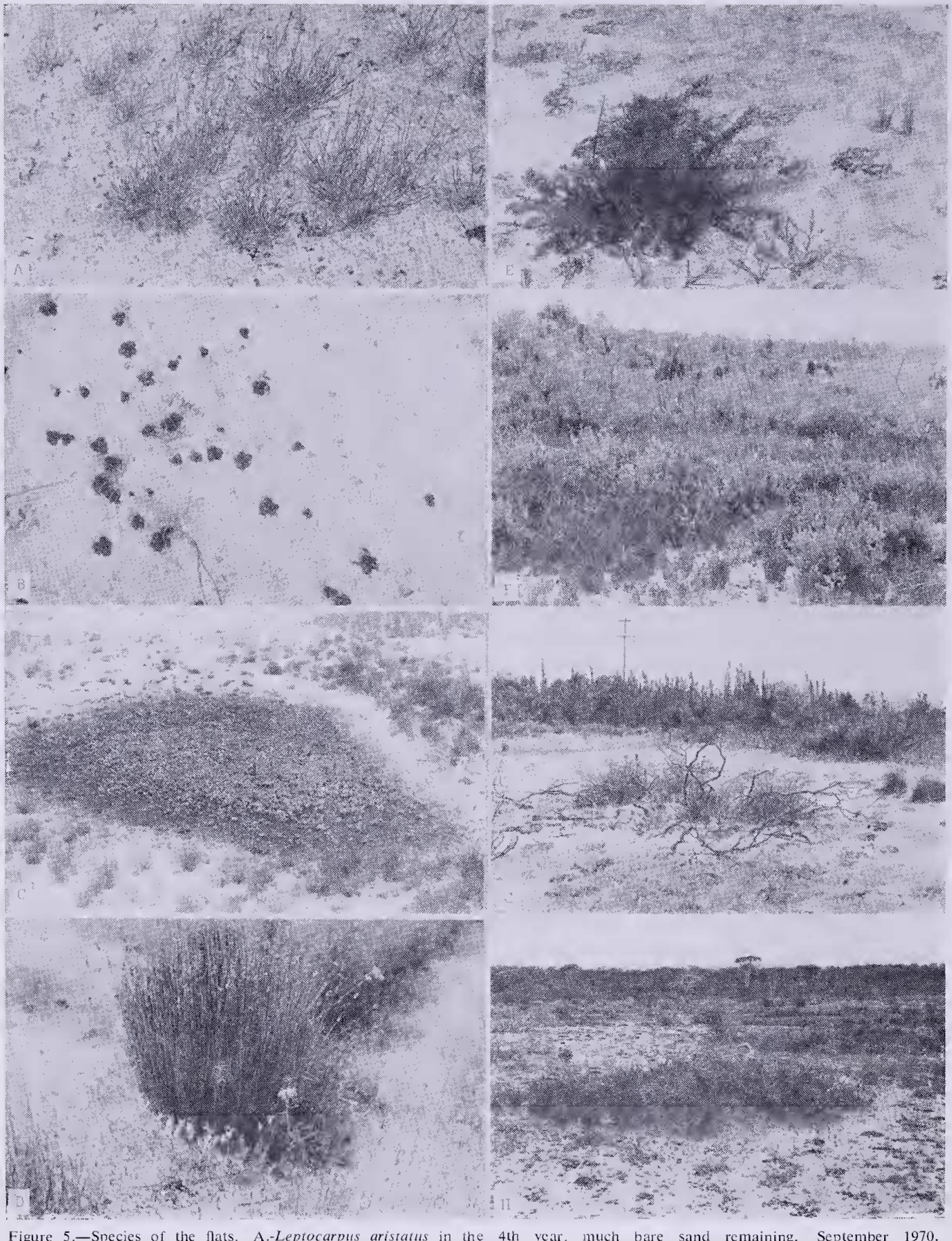

Figure 5.—Species of the flats. A.-*Leptocarpus aristatus* in the 4th year, much bare sand remaining. September 1970. B.-*Drosera bulbosa* on bare white sand after a summer fire. May 1961. C.-*Angianthus stricta* in a slight depression. November 1970. D.-*Stylidium calcaratum* at base of a clump of *Leptocarpus canus, Centrolepis aristata* right foreground. October 1967. E.-A. sprouting clump of *Grevillea thelemanniana, banksia telmatiaea* seedlings two years after fire in March 1958. April 1960. F.-Good seedling regeneration of *Banksia* in sixth year from fire in 1964. December 1969. G.-Two year regrowth of the mound building *Melaleuca bracteosa* on the western flat, unburnt *Actinostrobus* in background. April 1960. H.-Mounds on the central flat in the fourth year after fire in 1967, very poor recovery of the *Melaleuca*. Main sand ridge in background. Tall white stemmed *Melaleuca* and surroundings has escaped all fires. September 1970.

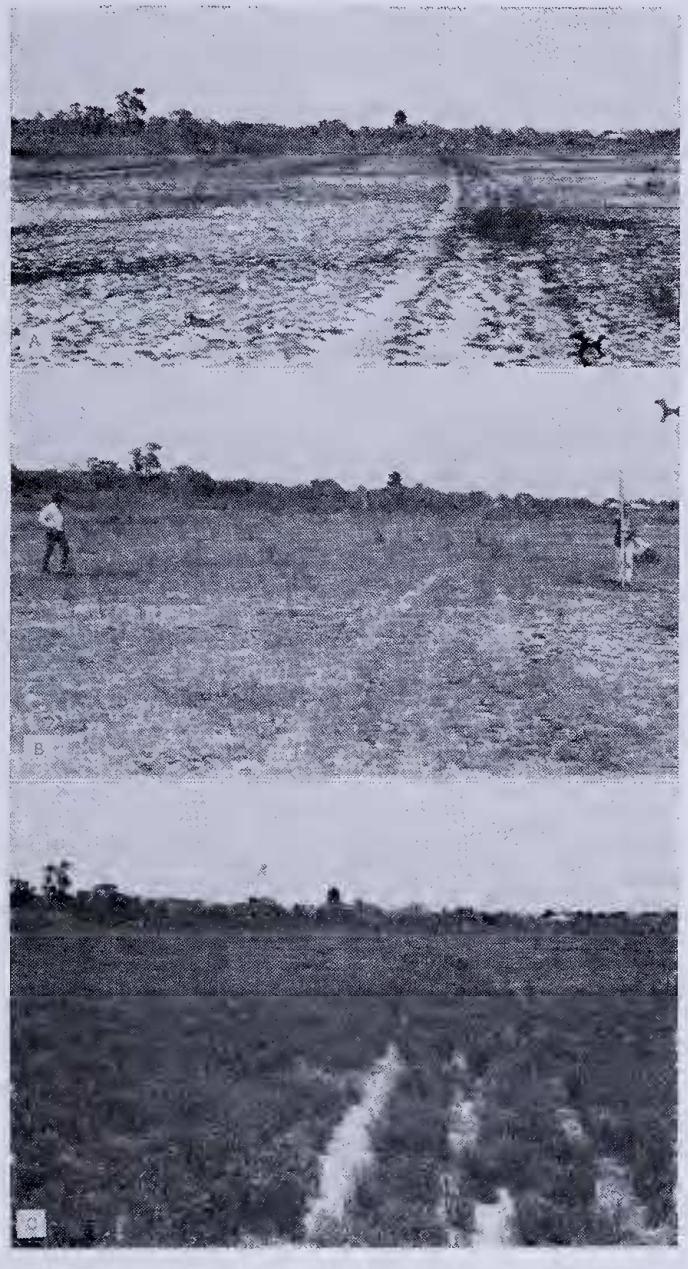

Figure 4.—The main *Leptocarpus* flat with an old cart track across it. A.-The burnt flat after a fire in January, unburnt ridge on left. May 1967. B. In the fourth year of regeneration. Shows the slow recovery of the *Leptocarpus*. The scattered sedge tufts are species which are not killed by fire. September 1970. C.-The *Leptocarpus* sward in its eighth year of regeneration from a fire in 1958. October 1965.

The flats—Leptocarpus sward with depressions and mounds.

Whereas recovery on the ridge is rapid, it is slow on the flats (Fig. 4). The whole appearance of the *Leptocarpus* meadow with its islands of big mound building *melaleucas*, is drastically changed. The dominant *Leptocarpus* is completely killed and the *melaleucas*, although sprouting take many years to regain their former shrub form. For the first year (Fig. 4A) the flats remain bare except for the occasional tufts of those sedges which are capable of sprouting and the old blackened bases of the burnt-off *Leptocarpus* clumps. The *Leptocarpus* seedlings although present the first year are minute and scarcely project through the loose sand. The seedlings do not grown as single plants but in tufts originating from a fruiting head (Fig. 5A). By the second year of growth they form a faint grey film over the sand and by the third to fifth year some have reached the flowering stage. By the 7th-8th year the meadow-like appearance is restored although the plants have not reached their maximum size (Fig. 4C).

Although the regeneration of the *Leptocarpus* is slow there is no other plant replacing it in the succession. The herbaceous geophytes of the flats, unharmed by fire as they died down before its occurrence, flower as usual in winter and spring and rather more profusely, probably benefiting from the additional nutrient from the ash. These however are more abundant at the levels slightly above the main *Leptocarpus* level.

The rather distinctive zone at the foot of the west-facing slopes which normally shows seasonal dominance of *Drosera gigantea* and *Ultricularia inaequalis* is particularly spectacular after fire when the *Leptocarpus* which hides the *Utricularia* has been removed. The ephemeral cover of tiny annuals, of which *Centrolepis aristata* is the most abundant and widespread, is much more visible on the fire stripped flats and plants of most species are larger than in unburnt areas. Slight depressions are often densely covered by *Calandrinia granulifera* or, where saline, by *Angianthus strictus* (Fig. 5C).

The larger saline depressions with *Halosarcia halocnemoides* normally escape fires (Fig. 1). The samphires are succulent and are surrounded by more or less bare areas, then by widely spaced *Leptocarpus* clumps before the dense swards of non saline parts. After fires, seedlings from the burnt *Leptocarpus* near the depressions after 4 years graded outwards from plants only 2-5 cm up to 15-20 cm and flowering.

Of the shrubs of the main level and slightly elevated areas of the flats, *Grevillea thelemanniana* (Fig. 5E) *Hakea varia* sprouted early and vigorously. Many seedlings were found of *Grevillea* but few of *Hakea*. *Banksia telmatiaea* was killed but regenerated well from seed. After the 1958 fire, seedlings in the first year grew to 4-5 cm with already well developed proteoid roots. A year later sizes were very varied, but mostly heathy plants 15-20 cm with some branching and, by the third year many were sturdy much branched bushes up to 30 cm tall and similar diameter. A particularly dense even aged stand below ridge still had no flowers in its sixth year and this was also true for plants of similar size and age after the 1964 fire (Fig. 5F). However, one or two plants have been seen with two flowers in their fifth year. *Calothamnus villosus* is also fire sensitive and regenerates from seed.

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The mound forming *Melaleuca bracteosa* (Fig. 5G) was not killed but recovered only very slowly so that the mounds for the first few years, with the protection of the large spreading bushes removed, tended to become flattened by erosion. Seedlings from the associated shrubs were spread over a wider area than the original site and developed very differently according to the microhabitat. After the 1958 fire on the central flat, in the first year seedlings of *Melaleuca, Hypocalymma, Calothamnus Acacia* and *Actinostrobus* were numerous. Over the next few years some fluorished and others failed to make satisfactory progress, though few died. Eight years after the 1958 fire, small stunted plants of *Acacia stenoptera, Actinostrobus pyramidalis* and *Calothamnus villosus* still survived although only some 5 cm high. This stunting seemed to be associated with increased salinity in the soil. *Acacia stenoptera*

Figure 6.—Series of photographs taken at the same site on the edge of the flat since the fire of March 1958. A.-November 6th 1958—In the foreground bare flat with burnt bases of *Leptocarpus* clumps, some herbaceous growth, left, on the ridge *Stipa compressa*, burnt trees with small epicormic shoots, on the right top of fallen *Melaleuca*, also showing in B, C, and D. B.-October 29th 1959—On the flat a faint grey film of small 2 year old *Leptocarpus*, massive regrowth of *Acacia saligna* on the bank, trees clothed in epicormic shoots. C.-October 1965—A more distant view of the site showing its position in relation to the scraped firebreak put down in 1964. *Leptocarpus* cover restored, dense shrub growth behind fallen *Melaleuca*. D.-November 5th 1970—Slight canopy on the eucalypts, dense bushy regrowth (centre) from the stumps of the burnt off *Melaleuca*; slender thirteen year old *Actinostrobus* (right background). E.-May 1972 after a fire in February 1972—Shows the slope up from the bare at to the eucalypts and adjacent *Xanthorrhoea* plants. F.-Octoher 29th 1975—In the fourth year of recovery, again dense regrowth of *Acacia saligna*, a low but dense growth of *Leptocarpus* on flat.

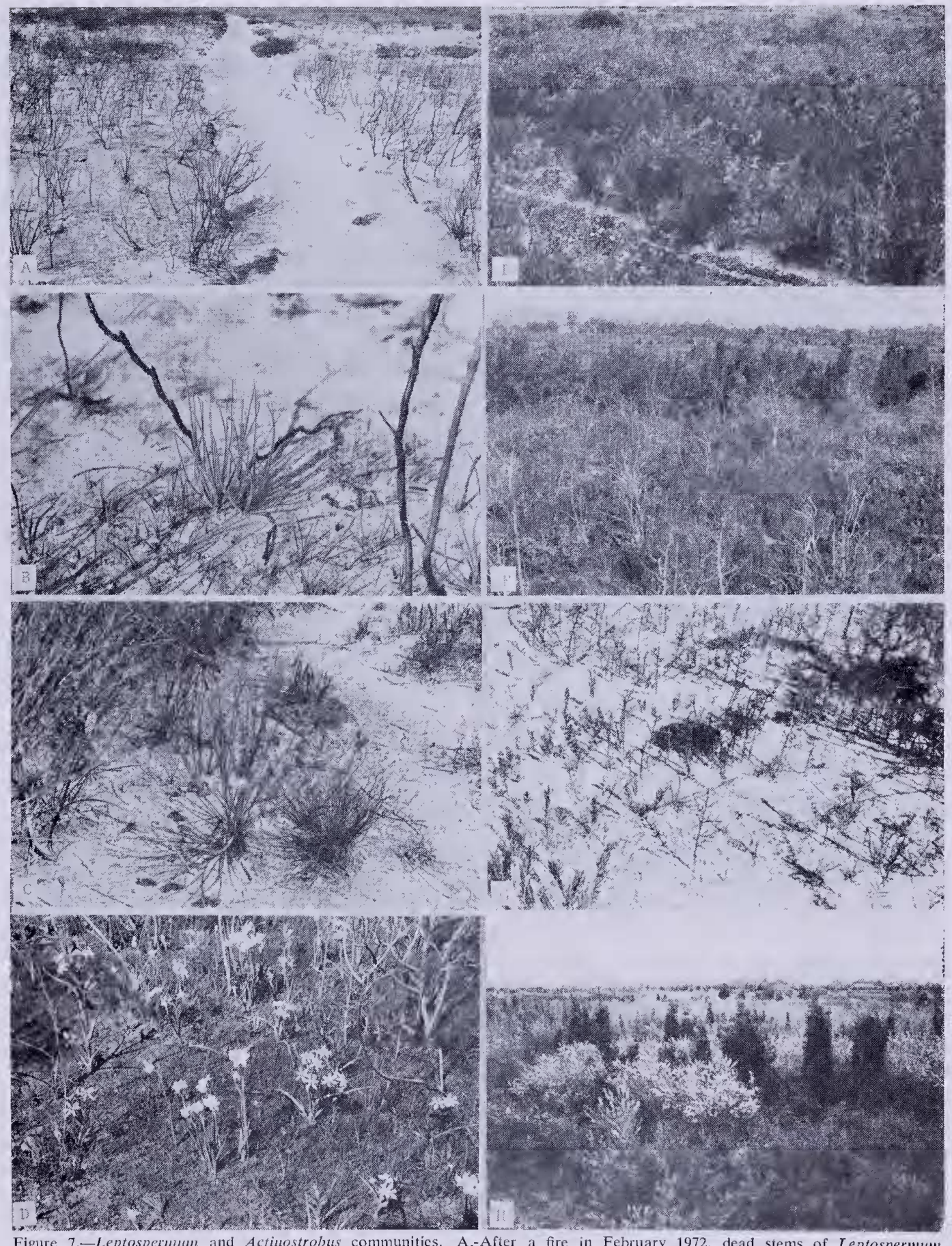

Figure 7.—*Leptospermum* and *Actinostrobus* communities. A.-After a fire in February 1972, dead stems of *Leptospermum*, unburnt *Leptocarpus* sward in background. May 1972. B.-Early regrowth of *Byblis gigantea* at the base of old stems which show the habit of branching; various monocotyledons sprouting in fore-ground. August 1972. C.-*Byblis* in flower, *Conostylis filifolius* right, *Cyathochaetae avenacea*, a sprouting sedge, overhanging left corner. October 1972. D.-*Tribonanthes variabilis* and *Burchardia multiflora* on a site lightly burnt the previous summer. September 8th 1972. E.-Restored community from an earlier fire in March 1958, *Leptospermum* in flower. October 1968. F.-A stand of *Actinostrobus* partly burnt some years earlier (1949), dead stems remaining but no regeneration, on the ground *Leptocarpus* and *Acacia lasiocarpa* in flower. August 1956. G.-Good seedling regeneration in an *Actinostrobus* community. *Actinostrobus* single plant centre foreground and many in background, *Hypocalymma* lower left corner. All are two year old seedlings from a 1958 fire. April 1960. H.-*Hypocalymma angustifolium* in flower in a mixed *Actinostrobus* community. August 24th 1981.

showed the thickening and yellowing so often associated with salt. Regrowth of the large *Melaleuca* bushes continued steadily but slowly and after eight years had reached less than half the prefire height. Build up of the mounds could not be followed for more than nine years as the whole area was burnt again in February 1967. After this fire, the regeneration of the mounds was very poor (Fig. 5H). Where mounds had been burnt in both 1964 and 1967, or in 1958, and 1964, some *Melaleuca* had completely failed to regenerate.

In more favourable situations, although the regrowth of the *Melaleuca* bushes was still slow, associated shrubs flourished. *Acacia lasiocarpa,* common on the mounds, was particularly abundant at the foot of the eastern slope of the western ridge. After the fires of 1958 and 1967, seedlings were very numerous and resulted over the next few years in a dense cover of bright green low bushes yellow with flowers in spring.

Leptospermum communities

In the *Leptospermum* zones (Fig. 7) change in plant cover through early years of the fire succession is shown to a marked degree. In a long unburnt stand the *Leptospermum ellipticum* bushes, (up to 1 m tall), completely overshadow other species. The associated sedge *Restio tremulus,* in which the hanging balls on the male plants give a distinctive appearance, is more conspicuous when the shrubs are smaller. As both of these species are killed by fire (Fig. 7A) the zone is dominated for several years by minor species.

After the 1958 fire, seedlings of *Leptospermum ellipticum* came up in aboundance but were not more than 2-3 cm high in September and by the end of the growing season in November were only 3-5 cm with six to eight small leaves above the cotyledons. In spite of the long hot summer mortality was very low and growth accelerated the next season. In the second and third years there was a marked difference between the seedlings in the flatter and lower *Leptospermum-Restio* zone and those on the contiguous better drained slope. In 1960 the seedlings of the lower level were still only about 15-20 cm tall and unbranched while those of the higher level averaged about 30 cm and were branching. By the end of this, the third growing season, a few of these flowered and at the end of the fourth year there was some flowering in the lower level also. Similar rates of growth and similar differences between upper and lower *Leptospermum* zones were observed after later fires, at the western foot of the main ridge.

Restio tremulus, the co-dominant of the lower levels was equally slow to regenerate. Small shoots, recognised as *Restio* by their flattened stems, grew very slowly and few plants had reached the flowering stage by the fourth year. Eight years after the 1958 fire on the steep western slope (Fig. 5C) the whitened stems of the dead *Leptospermum* still projected above the *Restio* which obscured the small *Leptospermum* plants. Four years later the *Leptospermum* overtopped the *Restio* and the old stems.

Through the early years of the slow growth of the dominants the subordinate species were flourishing in both the lower and upper *Leptospermum* zones. The sprouting shrubs *Hypocalymma angustifolium, Daviesia physodes* and *Hakea ceratophylla* grew vigorously and flowered profusely. *Lechenaultia expansa,* regenerating rapidly from seed, flowered particularly well in spring of the 2nd and 3rd year, thereafter gradually waning. *Beaufortia squarrosa* also grew rapidly from seed and some were flowering at 2 years old (April 1960), but in contrast to the more herbaceous *Lechenaultia,* continued to grow into sturdy woody shrubs still flowering well in long unburnt stands. The less frequent slender *Astartea fascicularis* was killed and regenerated from seed.

The herbaceous perennial insectivorous plant *Byblis gigantea* (Fig. 7B&C) sprouted and some plants had one or two flowers in the first year but with particularly good flowering in the 2nd and 3rd years. In the same zone as *Byblis, Conospermum huegeli* and *Anigozanthos viridis* were common. Herbaceous geophytes such as the common *Tribonanthes variabilis* and *Burchardia multiflora* (Fig 7D) and orchids, sundews, and small annuals were conspicuous on the burnt areas.

Actinostrobus communities

Actinostrobus pyramidalis (Fig. 7F) is killed by fire. Mature cones remain unoponed on the living plants and seed is released only after death. Numerous seedlings (Fig. 7G) have been found close to the parent plants after each of the fires but survival has been varied. After the March 1958 fire, seedlings with cotyledons and small shoots (2-4 cm) were seen in July and by November had ceased growth at 5-6 cm. In the 2nd year the 3 ranked appressed adult foliage had succeeded the 4 ranked juvenile leaves and heights of 10-15 cm in May and 20-25 cm in October had been reached. In the 3rd year a few plants had tiny cones which would not be ripe for another 18 months. After each fire a few of the biggest plants have had a few ripe cones at 5 or 6 years, most a year or two later. Because of frequent fires along the north west side of the reserve, where most of the *Actinostrobus* occurred before 1960, few plants have survived more than 10-15 years—a short life for a conifer. The plants are scattered through the community or in small groups rather than forming close stands as on a long unburnt site on an adjacent property.

Much of the undergrowth in the mixed *Actinostrobus* stands is similar to that in the *Leptospermum-Restio* community. The sprouting shrub *Hypocalymma angustifolia,* which also produces numerous seedlings (Fig. 7G), is particularly abundant in the repeatedly burnt sections (Fig. 7H). Several species of *Verticordia* are conspicuous after fires but relatively short lived. The annual composite *Brachycome pusilla* is very common.

Discussion

This description is in general terms as no quantitative work has been undertaken and visits to the site have ben irregular. All fires were summer ones the earliest in mid or late January and the latest in mid March. The western ridge has been burnt four times at intervals of nine years (1949, 1958, 1967, 1976). This interval would appear to be satisfactory for maintaining a healthy shrub community. The eastern ridge has had fires at different intervals on different sections of the ridge and consequently has different stages of the fire succession in different parts as the example given for 1970.

This is a fire tolerant vegetation as that of most of the south of Western Australia (Gardner 1957, Wallace 1966). Trees are not killed, foliage is renewed from epicormic buds along the branches, e.g. *Banksia attenuata* and most of the shrubs burnt to ground level in fires recover by sprouting from lignotubers or massive tap roots, e.g. *Jacksonia floribunda*. Persistent monocotyledons have rhizomes or otherwise well protected growing apices and the many herbaceous geophytes have inbuilt protection by dying down in summer to underground perennating organs. Species killed by fire regenerate well from seed, e.g. *Leucopogon conostephioides*.

Both ridge and flat species capable of shoot regeneration have the advantage not only of faster vegetative growth but of renewed flowering within one or two years while flowering from seedling plants takes longer. However, early reproduction is a feature of many of the non-sprouting species. The ability of *Actinostrobus* to produce ripe cones on small plants only 5-6 years old is unusual for a conifer and of value in a fire susceptible environment. Fire sesitive species of *Leucopogon, Beaufortia, Verticordia* and others flower when only 2-3 years old, but other fire susceptible species in the same communities flower much later. Nevertheless, therc is some evidence that the frequent fires of the last 20 year have reduced the populations of *Actinostrobus, Banksia telmatiaea, Leptospermum ellipticum* and some epacrids in parts burnt several times in close succession.

There is an extensive literature on fire in Australian vegetation, much of it listed in recent papers such as Gill (1981) and Purdie and Slatyer (1976). Adaptions such as those described for Yule Brook are well known in sclerophyllous vegetation. Two papers dealing with fire on the Perth coastal plain in vegetation similar to that of the sand ridges at Yule Brook are Whelan & Main (1979) and Baird (1977), one dealing with Banksia woodland on deep white sand at Jandacot the other a Banksia-Eucalypt woodland on deep yellow sand in Kings Park. In neither site is there underlying clay as at Yule Brook. Although there are differences in species composition on the three sites there are many species in common and the general pattern or regeneration is the same.

For fire regeneration on seasonally waterlogged clay flats like those on the Yule Brook Reserve I can find no published literature.

On this site there is a marked difference between the rapid recovery on the ridges and the much slower regeneration on the flats where the dominants are killed and seedling growth is slow. The *Leptocarpus* swards are replaced effectively though slowly by the very numerous seedlings. Apparent deterioration of the *Leptocarpus* appears to be due to salinity on the flats checking the growth of seedlings.

The scattered shrub mounds have been greatly reduced. These are important ecologically as they provide shelter and stable soil. The fringes of the mounds are a favourable habitat for many of the herbaceous species. The natural succession is for the mounds to increase in height and spread by accession of wind blown sand, plant debris and the addition of further plants in the existing shelter. In the present situation of frequent fires with consequent erosion of the mounds, regression is more evident than succession. Near the eastern boundary there are a few large and complex mounds which have escaped fire. These lend support to the idea given by Speck (1952) in his thesis that the mounds represent an early stage in succession to tall mixed *Actinostrobus* scrub.

Since 1967 thc main flat has been very denuded in comparison with its condition 20 years ago. Some of this is due to repeated burning of the *Leptocarpus* which requires 6-8 years for the dense swards to be re-established and some is apparently due to increased salinity. It is as yet uncertain how far fires, drought and changed drainage may have been involved in this apparent deterioration or whether with fewer fires and a succession of wet winters the changes could be reversed.

One of the unfavourable results of repeated fires has been to facilitate the invasion and numerical increase of weed species on both flats and ridges. Fires leave ground open for invasion, and weed cover of annuals which dry off in summer increases the fire danger.

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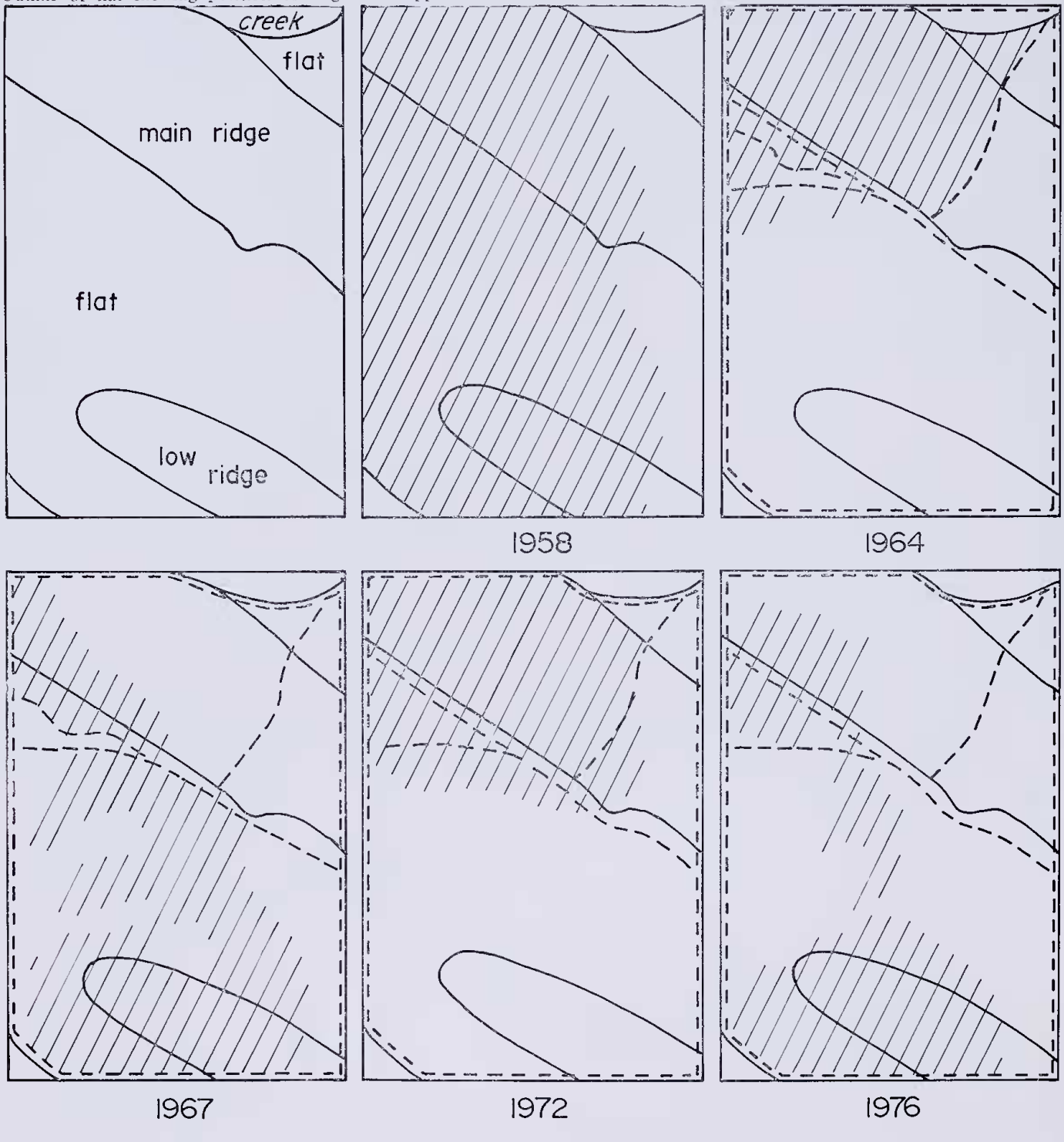
Appendix 1

Outline of flat showing position of ridges and approximate extent of each of the fires.



Appendix 2

The following lists give the response to fire of some of the more common perennial species. A species list for the reserve is given in the account of the vegetation of the Reserve. (Spek and Baird 1984).

A. Sand ridges—Banksia woodland and shrub covered slopes.

Trees—none are killed—sprouting from epicormic buds.

Sclerophyllous shrubs and fibrous monocotyledons.

Sprouting	Killed
Eremaea pauciflora	*Adenanthos cygnorum*
Jacksonia floribunda	*Leucopogon conostephioides*
Oxylobium capitatum	*Leucopogon* sp.
Hovea trisperma	*Gompholobium tomentosum*
Bossiaea eriocarpa	
Hibbertia hypericoides	
H. racemosa	
Petrophila linearis	
Stirlingia latifolia	
Eriostemon spicatus	
Conostephium pendulum	
Astroloma pallidum	
Conospermum sp.	
Casuarina humilis[2]	
Xanthorrhoea preissii	
Dasypogon bromeliifolius	
Patersonia occidentalis	
Lyginia barbata	
Amphipogon turbinatus	
Tetrariopsis octandra	
Schoenus curvifolius	
Conostylis spp.	
Thysanotus spp.	

B. Intermediate levels between ridge and flat—*Leptospermum-Restio* and *Actinostrobus* communities.

Sprouting	Killed
Hypocalymma angustifolium	**Leptospermum ellipticum*[1]
Hakea varia	**Actinostrobus pyramidalis*
Hakea ceratophylla	*Hakea sulcata*
Daviesia physodes	*Astartea fascicularis*
Viminaria juncea	*Verticordia* spp.
Byblis gigantea	*Beaufortia squarrosa*
Anarthria gracilis	**Restio tremulus*
Cyathochaeta avenacea	
Acanthocarpus preissii	
Schoenus sp.	

C. Flats—*Leptocarpus aristatus* sward and shrub mounds.

Sprouting	Killed
Hakea varia	*Banksia telmatiaea*
Grevillea thelemanniana	*Calothamnus* aff. *villosus*
Melaleuca bracteosa	*Acacia lasiocarpa*
Leptocarpus canus	**Leptocarpus aristatus*
Gahnia trifida	
Schoenus sp.	

D. Geophytes.

In all communities geophytes which die down and perennate through summer as underground corms tubers etc. are not killed. A few common geophytes of the wetlands are:—

Burchardia multiflora
Iribonanthes variabilis
T. brachypetala
Philydrella pygmaea
Drosera gigantea
D. bulbosa
D. heterophylla
D. neesii
Diuris spp.
Pterostylis nana

Notes:

* denotes dominant species.

[1] *Leptospermum ellipticum* has been renamed *Pericalymma ellipticum* (Thompson, J. (1983).—Redefinition and nomenclatural changes within the *Leptospermum* suballiance of the Myrtaceae. *Telopea*, **2**(4): 379-383.)

[2] *Casuarina humilis* has been renamed *Allocasuarina humilis* (Johnson L. A. (1982).—Notes on Casuarinaceae 2. *J.Adel.Bot. Gardens*, **6**: 73-87.)